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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PETROLEUM GEOLOGY OF THE ONSHORE PART OF HOPE AND KOTZEBUE BASINS, ALASKA: A REPORT FOR THE FEDERAL LANDS ASSESSMENT PROGRAM (FLAP)

by

Michael A. Fisher[1]

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[1]U. S. Geological Survey

345 Middlefield Rd

Menlo Park, CA 94025

Figure 1. Regional geography of the Hope and Kotzebue basins, Alaska. The box outlines the general area described in this report.

Geography and History of Petroleum Exploration

The main parts of Hope and Kotzebue Basins lie offshore from northern Alaska, beneath the southeastern Chukchi Sea, and contain Cenozoic strata as thick as 5-6 km (Figures 1 and 2; Eittreim et al., 1978, 1979; Tolson, 1988). This report concerns the parts of these basins that underlie onshore areas and offshore areas that are within 3 miles of the coast. The onshore parts of these basins occupy the northern Seward Peninsula and the lowlands that fringe the east and north sides of the Chukchi Sea. Most of the exploration for hydrocarbons has involved collecting marine and scattered onshore seismic reflection data, but two onshore exploratory wells, drilled by Chevron Oil Company on native corporation lands, are located where the basin fill is thin (Figure 2). A lease sale for petroleum for the offshore part of the Hope Basin is scheduled for mid 1992.

Structural Setting

The Hope and Kotzebue Basins lie wedged between exposures of two distinct types of basement rock: (1) the deformed and metamorphosed Paleozoic rocks that outcrop on the Seward Peninsula, Siberia, and in the western Brooks Range, and (2) strongly deformed Cretaceous turbidite sequences and volcanic rocks that are exposed east of these basins (Figure 2). Hope and Kotzebue Basins are fault-bounded lows developed within these basement rocks. The Hope Basin lies northwest of the Kotzebue arch, a large east-west trending basement high. This basin appears to be a half graben that is deepest (5-6

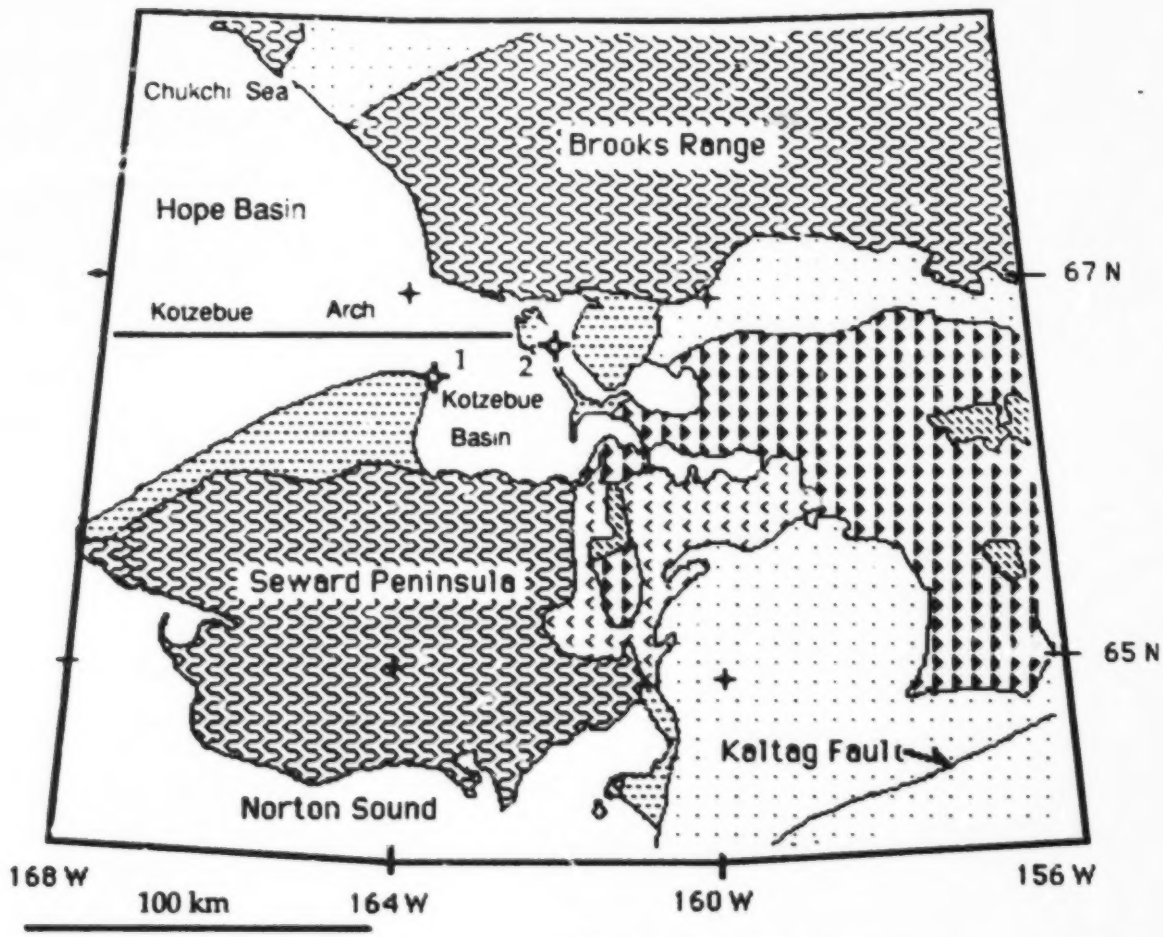

Figure 2. Regional geology of the Hope and Kotzebue basins. Explanation of lithologic symbols is on Figure 3. Well number 1 is at Cape Espenberg, number 2 is at Nimiuk Point.

km) along the north side of the arch. Southeast of the Kotzebue Arch lies Kotzebue Basin, which is distinct from Hope Basin. Hence, "onshore Hope Basin" actually refers to the onshore part of Kotzebue Basin. The fill of the Kotzebue Basin is about 1 km thick near the Kotzebue arch but thickens southeastward from this arch to about 3 km below the basin center. Seismic reflection data show that this fill has primarily subhorizontal bedding that onlaps the basin flanks. In onshore areas, wells and scattered proprietary seismic sections show that probable Cenozoic fill is thin (primarily less than 1 km) but that thicker (1.5-2 km) Cenozoic units are present in isolated half grabens. Sparse gravity stations comprise the only public geophysical data obtained over the onshore basin; these data indicate that the basin appears to be shallow.

Lithology and Age of Rock Units

Basement rocks under onshore areas east of the Kotzebue Basin are likely to be the deformed Cretaceous volcanigenic turbidite sequences and andesite. These rocks are locally intruded by Cretaceous plutons. Near Norton Sound (south of the Seward Peninsula) these rocks have been extensively studied and are highly consolidated. They are characterized by poor porosity and permeability, and laumontite

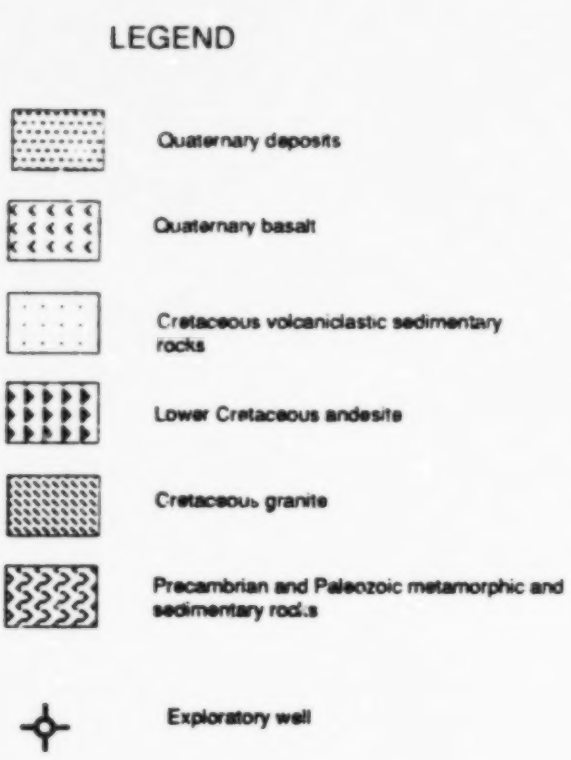

Figure 3. Explanation for Figure 2.

completely occludes pore spaces in rocks exposed over large areas (Patton 1973; Hoare et al., 1964). The part of Kotzebue Basin on the Seward Peninsula overlies a basement composed of deformed and variably metamorphosed Paleozoic and Precambrian rocks. On the Seward Peninsula these rocks are regionally metamorphosed at least to blueschist facies, but gneiss and amphibolite facies rocks are also exposed locally (Sainsbury, 1975; Hudson, 1977). Paleozoic rocks exposed north of Hope Basin are less metamorphosed than are those on the Seward Peninsula (Campbell, 1969). Nonetheless, both wells drilled into Kotzebue basin penetrated metamorphosed basement rocks, mainly schist, slate and limestone.

The age and lithology of the fill within Kotzebue Basin is known from scattered outcrops and two exploratory wells. These data suggest that the fill is primarily Cenozoic because the wells penetrated late Eocene basalt near the base of the fill. Basalt from the well at Cape Espenberg yielded a K/Ar age of 40.7+-2 m.y., and basalt from the well at Nimiuk Point suggests an extrusive age of 42.3+-10 m.y (Alaska Oil and Gas Commission, 1981a,b). The maximum age of this fill is not known: where the fill thickens into offshore areas of the Kotzebue Basin, the fill could be older than Eocene. By analogy to Norton Basin, which lies south of the Seward Peninsula, the Kotzebue Basin could contain rocks as old as Paleocene (Turner et al, 1983a,b). The fill within Kotzebue Basin, however, onlaps shoreward, so that the more inland parts of the basin include a progressively thinner, younger part of the Eocene and younger rocks penetrated in the wells. The lithology of the basin fill is known from the two wells. Rocks penetrated in the Cape Espenberg well are richly volcanigenic from total depth at 2400 m to about 1500 m (American Stratigraphic Company, 1977a,b). Above 1500 m the volcanic fraction decreases in abundance, and the section includes much sandstone and shale. Coal stringers and claystone also become more common upward. The coal points to a nonmarine environment for much of the fill. In the offshore parts of the basin, the fill could include marine or lacustrine deposits. Again by analogy to Norton Basin, the deep fill in the Kotzebue Basin is likely to be nonmarine, and the shallower fill is probably marine.

Petroleum Geology

Hope and Kotzebue basins formed by rifting, and basins that develop by this tectonic mechanism commonly have high heat flows because of the tectonically thinned crust that floors them. High heat flow could aid formation of hydrocarbons. As the basin matures the heat flow eventually decreases to normal continental values

(25 °C/km). For example, Norton Basin formed by crustal extension, and the present heat flow in this basin is known from COST well data to be high (37-45 °C/km, Turner et al., 1983a,b) and was probably higher in the past. Bottom-hole temperature data from the wells drilled in the Kotzebue Basin scatter greatly, yielding a poorly constrained estimate of 50 °C/km for the geothermal gradient (Fisher, 1982). However, by analogy to Norton Basin, the heat flow in the Kotzebue Basin might be about 40 °C/km. Despite this favorably high inferred heat flow, rocks as old as Eocene that were penetrated by the wells in the Kotzebue Basin are at best only transitionally mature for generating hydrocarbons; most of the section is immature. This low thermal maturity is shown by both vitrinite reflectance data and thermal alteration indices. Pyrolysis data show that rocks penetrated by the wells have poor potential to generate hydrocarbons. This low potential results from the quality of kerogen in the basin fill, which kerogen is primarily type III, coaly and woody. This type of kerogen would produce chiefly gas when heated. If deep offshore parts of the basin contain lacustrine or marine rocks, source rocks more favorable for oil would be present. Even so, to be trapped in the thin onshore parts of the basin, these hydrocarbons would need to migrate long distances along pathways for which no evidence exists. The thin basin fill onshore is not likely to include indigenous oil because potential source rocks within this fill are most likely immature. The fill penetrated in the wells achieves a vitrinite reflectance of 0.6 at about 1700 m so the fill onshore would need to be at least as thick to produce oil. However, biogenic gas may be present. Paleozoic basement rocks penetrated by the wells yield vitrinite reflectances of about 2.1, so these rocks are overmature and are not likely to be source rocks for hydrocarbons. Where Cretaceous rocks form basement, the generation of hydrocarbons within basement is just as unlikely; these rocks include predominantly type III kerogen and have been heated to well above the oil window and possibly above the gas window.

Principal Plays for Petroleum

The only potential hydrocarbon play in the onshore and nearshore parts of the Hope and Kotzebue Basins is highly speculative and involves fault traps in nonmarine sandstone reservoirs around the periphery of local half grabens. Inasmuch as the onshore fill is insufficiently thick to produce oil and basement rocks are overmature and not likely to be source rocks, these potential fault traps must either be charged by long distance migration from thicker, offshore parts of the basin or be filled with biogenic gas.

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